Early Geophysics at LBL, 1976–1982

by Norman E. Goldstein

In the summer of 1976, I was working for the International Division of Cities Service Corporation. One day in August, upon returning to our Sydney, Australia office after a month in The Philippines and Malaysia searching for copper deposits, I was asked by the office secretary to call my wife immediately; Susan had been frantically trying to reach me for several days. Fearing the worst, I reached Susan at her parents' house in California and learned that my former UCB classmate, now Professor, Frank Morrison had been trying to reach me, and would I call him immediately; it was something to do with a job at LBL. After three years of living in Tulsa, and experiencing one tornado too many, Susan was seriously looking forward to our return to California. I agreed to meet her in Berkeley for an interview with Frank and Paul Witherspoon a few days hence. I was not sold on the idea of changing jobs and leaving my friends and co-workers at Cities Service Corporation, but after many years of working in the private sector for big corporations, I knew the insecurity of working for organizations in which whole departments could be laid off without notice, to please Wall Street bankers and investors.

Initially I worried that I had absolutely no knowledge of how LBL operated or how it was funded by the Energy Research Development Agency (ERDA), predecessor to DOE. All I knew was that ERDA, created as a direct result of the OPEC-led oil crisis, had been sending increasing funding to Frank and Paul for geothermal energy research at LBL, where Frank and Paul now had joint appointments (in the new Energy and Environment Division that was created in 1973). I had even hired, as a consultant in 1976, one of Frank's graduate students named Abijit Dey to do some geophysical modeling, using an advanced code he developed with ERDA funding. From Abijit, I learned that Frank and his students, notably John Henry Beyer, were engaged in extensive geophysical studies in northern Nevada.

Over the telephone, Frank said they wanted to consider me for the job of taking over one piece of the geothermal program; namely, geothermal exploration technology development. By that time, none of the UCB faculty researchers had the time to manage the growing number of LBL projects in geophysics, plus deal with their own University-based research and teaching commitments.

My introduction to LBL began as Frank gave me a quick tour of the areas of LBL he knew best, starting at Building 14, where electrical and mechanical techs designed and assembled some of the tools that Paul, Frank, and seismologist Tom McEvilly needed for their Northern Nevada geothermal exploration program. The interior walls and storage cabinets of 14 where covered with 10 years of *Playboy* centerfolds, very non-PC even for those days, but that there was, nevertheless, a very professional and serious side to the working environment ruled by Ray Solbau and Don Lippert. In deference to the women that would be hired, all the controversial centerfolds in 14 were taken down two years later.

After a quick look at the main fabrication shops, Frank took me down to the LBL Geothermal offices that were scattered about on the first and second floors of Building 90. Paul Witherspoon, the enthusiastic head of the Geothermal Program, whom I had known from my graduate student days at UCB, occupied an office in very much the same location as the present-day ESD Division office. There, he and his deputy Ken Mirk, a mechanical engineer, interviewed me while we all munched on peanuts that Paul had in a big bowl on his conference table. The table and floor were littered with empty shells. By the look of things, no one had bothered to clean up the shells in some time. Clearly, Paul was too preoccupied with the exciting research in progress to care how his office looked.

The geothermal program consisted of three main components: exploration technology development and evaluation; reservoir engineering and well testing; and energy conversion technologies. Together, these three efforts brought in over $1 million a year to the lab, a virtual bonanza in the days when a the starting salary for a scientist might barely exceed $20K a year and where most of the geothermal program researchers were graduate students of Paul, Frank and Tom. The few non-faculty LBL career scientists in the earth sciences group included Hal Wollenberg, John Apps, and Oleh Weres. Each was investigating various aspects of geothermal rock and water chemistry, and they occupied small offices on the second floor of 90.

The second floor of 90 was the domain of the Mechanical Engineering Department headed by Paul Hernandez. Paul's engineers filled the small window offices on the north end while the entire space between the offices was one huge open area filled to capacity with large drafting tables at which an army of technicians labored over elaborate schematics for new experimental facilities being planned for LBL and other accelerator sites. Located among the host of engineers were Bob Fulton and Bill Pope who, with Ken Mirk, were working on the design, construction and testing of advanced heat exchangers for improving the thermal efficiencies of low-temperature geothermal fluids. The Geothermal Group had but one part-time secretary, Maggie Peterson, who was primarily the secretary for Mechanical Engineering, and who became increasingly more peevish because of all the work being thrown at her by Paul Witherspoon and his group.

Following my brief tour of Building 90, Frank took me to Building 50A to meet the Acting Division Director of E&E, Bob Budnitz, a young nuclear physicist. Bob was enthusiastic about the future prospects of the geothermal group, despite his limited understanding of geosiences. Bob confirmed what I had earlier inferred from Paul Witherspoon—namely, that LBL provided an intellectual freedom and absence of restrictions unimaginable in private industry. I have to say that my interview with Budnitz was another factor that brought me to the lab.

I officially joined LBL in the first week of October 1976, never believing that LBL would be my ultimate employer. Knowing that I needed a temporary place to stay, Frank Morrison put me in contact with a new graduate student, Bjorn Paulsson, who was looking for someone to share a two-bedroom apartment on Milvia Street. Bjorn, a veteran of the Swedish Air Force for which he had flown Saab jet-fighters, was equally handy in the kitchen as in pursuing his PhD. He would later develop a small-diameter cross-hole seismic system that he used to study rock fractures for the Stripa Project in Sweden. As the first serious attempt to evaluate an underground repository for the storage of nuclear waste, Stripa was the model for the Yucca Mountain Project.

My first jobs at the lab were to prepare a set of proposals for 1977 funding and to help write, edit, and publish, as LBL Technical Reports, a backlog of partially completed geophysical deliverables that Larry Ball in ERDA's Geothermal Division was demanding. At issue was the need for LBL to conclude its evaluation of several geothermal areas so that the results could be made public and the lands could be reopened for leasing.

Writing the proposals was the easier task, because I quickly discovered that the three faculty members of the LBL geophysics program—Frank in Mineral Engineering, Tom in Earth Sciences, and John Clarke in Physics—already had very clear concepts of what they wanted to pursue. After meeting with them separately, my chunk of the LBL research proposal for 1977 fell into place.

During the next few years, several significant new geophysical technologies would be developed as a result of the studies begun by the UC faculty researchers and the solid support we had from ERDA and then, in 1977, from DOE. John Clarke and his two post-docs, Tom Gamble and Wolf Goubau, would develop and demonstrate the feasibility of using superconducting magnetometers called SQUIDs, based on the Josephson-Junction effect, to make highly sensitive, three-component magnetic field measurements. From that, they developed the Remote-Reference Magnetometer Technique (RRM), for eliminating the noise errors that had seriously plagued all previous attempts to obtain reliable electromagnetic soundings of the earth by observing naturally occurring electric and magnetic fields. In spite of early skeptics elsewhere, the scientific validity of the RRM technique was proven through a series of careful field experiments and was soon adopted by practitioners of the magnetotelluric (MT) method, the method that is commonly used for conductivity versus depth soundings.

Because SQUIDs had to be maintained at liquid helium temperatures, they were extremely difficult to use for long periods in the field. Eventually, SQUIDs were replaced with high-sensitivity, low-noise induction-coil sensors that were developed on campus by Hugo Conti, a brilliant inventor working for Frank Morrison. Hugo commercialized the coils and left UCB to form what became a successful company called Electromagnetic Instruments (EMI). Among those who later joined EMI were former LBL geophysicists Mike Wilt and Ed Nicholls, whom I hope profited well when EMI was purchased by Schlumberger.

Frank Morrison was a strong proponent of using ultra-large controlled-source dipole fields to gain information on rock and fluid conductivities at depths of over 1 km. But the engineering for a mega-source electromagnetic (EM) system was too big a job to be done on campus. With funds from DOE and help from Gene Binall in the LBL Electronics Department, we selected a young engineer, Carlos Riveros, to design a solid-state switch that would deliver more than one ampere of current, over a range of ultra-low frequencies, into a square transmitting antenna 1 km on a side, to obtain dipole moments of over 10^6 without inductive loss. The primary energy source was a 60 kW motor-generator (MG) that Don Lippert found in salvage. The MG set was mounted onto a one-ton truck chassis, thus making it possible to drive the lumbering source from place to place within a survey area. The EM-60, as it was called, never caught on as a practical exploration tool, but it did stimulate interest in "mega" source dipoles. The technique provided LBL researchers with a huge amount of excellent field data at geothermal areas, thanks in part to the hard work and ingenuity of two young LBL scientists, Mike Wilt and Mitch Stark, who I hired in 1978 to conduct the field surveys; and to several of Frank's graduate students, including Ki Ha Lee and Mike Hoversten, who developed the inversion algorithms needed to convert the raw data into conductivity depth soundings. The EM-60 also led to later research in surface-to-borehole EM technology and in mapping the geologic structure beneath the Columbia River basalts.

Because I needed a full-time seismologist on the LBL staff, I hired the talented Ernie Majer as soon as he finished his Ph.D. thesis under Tom McEvilly. Ernie continued his earth science investigations using man-made and natural seismic energy sources. In an early campus-lab project, Ernie and Tom spearheaded the development of the Automated Seismic Processor (ASP); the first mobile, automated (computer-based) processor that could identify, measure, and locate very small seismic events (microseisms) in real-time. The ASP was installed in a white bread van whose sides were emblazoned with depictions of a large green serpent. Microprocessor computer capabilities were advancing so rapidly during the early 1980s that the prototype ASP never became commercial. However, the early success of the ASP encouraged other research groups to build more powerful versions of a real-time processor for monitoring natural hazards.

Once Paul Witherspoon's programs achieved significant size and importance, the Earth Sciences Division was created in 1978, with Paul as its first Director. By this time, Paul initiated both the Stripa Project in Sweden and the Cerro Prieto Geothermal Project. Our ESD staff and overall funding level more than doubled between 1977 and 1978 during which time Bo Bodvarsson, Sally Benson, and Karsten Pruess (among many others) joined the Geothermal Program, and ESD took over the entire first floor of 90. Because Paul was totally involved in Stripa planning, he asked me to head the growing Geothermal Program which, thanks to Paul, was becoming heavily involved in a multi-year joint project with the Comisión Federal de Electricidad (CFE) at their Cerro Prieto field, 30 km south of Mexicali, Mexico. Marcelo Lippman became our Cerro Prieto program coordinator, as well as one of the over 20 LBL researchers that actively worked with CFE scientists and engineers until DOE ended the project in 1982. Because of the large amount of money flowing into the ESD Geothermal Program, Paul wisely decided to give me budgeting, accounting, and reporting help. John Phillip, a recent retiree from the DOE Budget Office in Oakland, came aboard to manage everything that had to do with geothermal finances. John in turn plucked Dee Schmidt out of the LBL Budget Office to do the heavy number crunching and to prepare the monthly financial reports for each of our many project accounts.

The CP project was unique in many ways, one of which was that it gave us unrestricted access to all the drilling, well testing, production and geologic data that CFE had. With this foundation, CFE and LBL developed a wealth of new scientific and engineering information that revealed the size (production capacity) and behavior of a huge high-temperature hydrothermal system undergoing fluid extraction. Regarding our numerous geophysical studies, Mike Wilt and I were able to demonstrate beyond doubt that highly precise, repetitive gravity and electrical observations provided accurate indications of how the hydrothermal system was responding to hot water production and recharge. We were greatly aided by the field efforts of two special scientists. Bob Corwin, one of Frank's former PhDs and an expert in electrical self-potential (SP), ran very important SP measurements for us, and Professor Rosie Grinnell of CSU Long Beach conducted the repetitive microgravity surveys. I would like to believe that our early efforts at 4-D geophysical measurements (the fourth dimension being time) was the impetus for similar studies by the oil and gas industry.

By 1978, ESD's geothermal research interests turned northward into Oregon and the Cascades. Working with Dave Williams, a U.S. Geological Survey (USGS) geologist assigned to DOE's Geothermal Division, Hal Wollenberg and I initiated LBL studies of the low-temperature Klamath Falls geothermal system, and then we developed a multiyear, multidisciplinary evaluation of the geothermal potential of Mt. Hood, an active Cascade Range stratovolcano 50 miles east of Portland. Mt. Hood provided an opportunity to apply some of our geophysical technologies, such as remote reference magnetotellurics and the EM-60, to an entirely new geologic setting. The Mt. Hood science team, including UC graduate students Mike Hoversten and Ed Mozley, was able assemble a science-based schematic of the thermal and geological structure as well as the geothermal fluid pathways of the volcano.

In closing this brief chapter describing the earliest days of ESD, I would just like to mention the name of David Johnston, a young USGS geologist-vulcanologist who worked with us on the Mt. Hood project. David was killed in May 1980 as a result of the Mt. St. Helens eruption, while manning his observation station five miles from the point of eruption. As for our ESD geophysical staff, none would suffer anything more serious than sunburn, insect bites, and scratches during our years of fieldwork; a tribute to the safety culture instilled by our techs, Don Lippert and Ray Solbau, to whom we all owe a great deal of gratitude for their abilities in the office, shops, and field.